

Material Properties (MP) Package Reference Manual

The MELCOR Material Properties package models many of the properties needed by the various physics packages. This is done by using analytical laws, correlations, or linear tables. New materials and their properties may be defined through user input, and properties for default materials may be redefined by user input.

This document identifies the default material property values and functions used in the MELCOR MP package. References for the data are provided. Detailed descriptions of input requirements are provided in the MP Package Users' Guide.

The thermodynamic properties of water vapor and liquid water are contained in the H₂O package and cannot be modified through user input. Properties of noncondensable gases are calculated by the NCG package. A description of the default values and available user input options is provided in the MELCOR NonCondensable Gas (NCG) Package Users' Guide.

CORCON and VANESA properties are included in the Cavity (CAV) and RadioNuclide (RN) packages, respectively. See the reference manuals and users' guides for those packages.

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1. Default Material Properties

The MELCOR Material Properties (MP) package models many common properties needed by the various phenomenological packages through the use of analytical laws, correlations, and tabulated values. These properties include thermodynamic state and transport properties needed for structural materials, as well as transport properties for water and noncondensable gases. (Thermodynamic state properties for these fluids are provided separately by the H2O and NCG packages; see the NCG/H2O Reference Manual.)

In a few cases, stand-alone codes that have been wholly integrated into MELCOR still use properties defined within those codes; a notable example is CORCON, which has been integrated into the Cavity (CAV) package. Also, properties unique to a package, such as those for trace species used in the RadioNuclide (RN) package, are generally modeled within that package. The Core (COR), Fuel Dispersal Interactions (FDI), and Heat Structures (HS) packages use principally the structural materials properties, while the Control Volume Hydrodynamics (CVH), Engineered Safety Features (ESF), Containment Sprays (SPR), and RN packages use principally the fluid transport properties.

The following 34 materials, listed with their mnemonic identifiers, are defined in the Material Properties package:

- | | |
|-----------------------------------|---------------------------------|
| 1. Water (WATER) | 19. Carbon Dioxide (CO2) |
| 2. Steam (STEAM) | 20. Carbon Monoxide (CO) |
| 3. Air (AIR) | 21. Nitrogen (N2) |
| 4. Hydrogen (H2) | 22. Nitric Oxide (NO) |
| 5. Helium (HE) | 23. Nitrous Oxide (N2O) |
| 6. Argon (AR) | 24. Ammonia (NH3) |
| 7. Deuterium (D2) | 25. Acetylene (C2H2) |
| 8. Zircaloy (ZR) | 26. Methane (CH4) |
| 9. Zirconium Oxide (ZRO2) | 27. Ethylene (C2H4) |
| 10. Uranium Dioxide (UO2) | 28. Uranium Hexafluoride (UF6) |
| 11. Stainless Steel (SS) | 29. Aluminum (ALUM) |
| 12. Stainless Steel Oxide (SSOX) | 30. Aluminum Oxide (AL2O3) |
| 13. Boron Carbide (B4C) | 31. Cadmium (CADM) |
| 14. Silver-Indium-Cadmium (AGINC) | 32. Stainless Steel 304 (SS304) |
| 15. Uranium Metal (UMETL) | 33. Lithium Aluminum (LIAL) |
| 16. Graphite (GRAPH) | 34. Uranium Aluminum (UAL) |
| 17. Concrete (CON) | 35. Carbon Steel (CS) |
| 18. Oxygen (O2) | |

Material 11, Stainless Steel (SS), is a type 347 stainless steel and is typically used in the Core package, whereas material 32 (SS304) is a type 304 stainless steel.

The following properties are defined in the package:

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	Type	Units
1. Enthalpy as a function of temperature	Tabular	J/kg
2. Temperature as a function of enthalpy	Tabular	K
3. Specific Heat Capacity as a function of temperature	Tabular	J/kg-K
4. Thermal Conductivity as a function of temperature		
a. From tables	Tabular	W/m-K
b. From Eucken correlation and Wassijewa equation	Calculated	W/m-K
5. Dynamic Viscosity as a function of temperature		
a. From tables	Tabular	kg/m-s
b. From Chapman-Enskog equations and Lennard-Jones potential parameters	Calculated	kg/m-s
6. Binary Diffusion Coefficient		
a. Function of temperature and pressure	Calculated	m ² /s
b. From Chapman-Enskog equations and Lennard-Jones potential parameters	Calculated	m ² /s
7. Density		
a. Constant	Constant	kg/m ³
b. Function of temperature	Tabular	kg/m ³
c. Function of temperature and pressure	Calculated	kg/m ³
8. Melting Temperature	Constant	K
9. Latent Heat of Fusion	Constant	J/kg

Default values are provided for some, but not all, combinations of materials and physical properties. Table 2.1 summarizes the default values available. A 'T' indicates that the default function can be changed through user-defined tabular functions and an MPMATnnnmm input record. A 'C' indicates that the default function can be changed through user-defined constant values input on an MPMAFnmm record. An 'X' indicates that the default function cannot be changed through user input. A blank space indicates that no default is provided, but may be supplied by the user, although in some cases that property for that material may not be used by MELCOR.

Also shown is the mnemonic(s) used to add new values or alter the default values through user input for those properties which can be changed.

Sections 1 through 10 identify the default values for those combinations defined in MELCOR. User definition of the materials properties is also discussed in each section.

2. Specific Enthalpy as a Function of Temperature

The specific enthalpy may be computed from either a user-specified tabular function or a MELCOR default table.

The user-specified tabular function to define a new material or to override the default table for an existing material is invoked by using a standard tabular function (see the TF Package Users' Guide) to input the enthalpy (J/kg) as a function of temperature (K). Negative enthalpies are permitted. Currently, there are no checks made on the consistency of user-input values for enthalpy, specific heat capacity, melting temperature, and latent heat of fusion; this could be rectified in future code versions.

The following materials have default tables for enthalpy:

Zircaloy	Graphite
Zirconium Oxide	Aluminum
Uranium Dioxide	Aluminum Oxide
Stainless Steel	Cadmium
Stainless Steel Oxide	Stainless Steel 304
Boron Carbide	Lithium Aluminum
Silver-Indium-Cadmium	Uranium Aluminum
Uranium Metal	Carbon Steel

Table 2.1 Default material properties, property mnemonics, and user input capabilities.

Property*:	1	2	3	4a	4b	5a	5b	6a	6b	7a	7b	7c	8	9
Mnemonic:	ENH	TMP	CPS	THC	SIG EPS	VIS	SIG EPS	n/a	SIG EPS	DEN	RHO	n/a	MLT	LHF
WATER				T		T								
STEAM				T	C	T	C		C			X		
AIR				T	C	T	C		C			X		
H2					C	T	C		C					
HE					C		C		C					
AR					C		C		C					
D2					C	T	C		C					
ZR	T	T	T	T						C	T		C	C
ZRO2	T	T	T	T						C	T		C	C
UO2	T	T	T	T						C	T		C	C
SS	T	T	T	T						C	T		C	C
SSOX	T	T	T	T						C	T		C	C
B4C	T	T	T	T						C	T		C	C
AGINC	T	T	T	T						C	T		C	C

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Property*:	1	2	3	4a	4b	5a	5b	6a	6b	7a	7b	7c	8	9
Mnemonic:	ENH	TMP	CPS	THC	SIG EPS	VIS	SIG EPS	n/a	SIG EPS	DEN	RHO	n/a	MLT	LHF
UMETL	T	T	T	T						C	T		C	C
GRAPH	T	T	T	T						C	T		C	
CON			T	T							T			
O2					C		C		C					
CO2					C		C		C					
CO					C		C		C					
N2					C		C		C					
NO					C		C		C					
N2O					C		C		C					
NH3					C		C		C					
C2H2					C		C		C					
CH4					C		C		C					
C2H4					C		C		C					
UF6					C		C		C					
STEAM + AIR								X						
STEAM + H2								X						
ALUM	T	T	T	T						C	T		C	C
AL2O3	T	T	T	T						C	T		C	C
CADM	T	T	T	T						C	T		C	C
SS304	T	T	T	T						C	T		C	C
LIAL	T	T	T	T						C	T		C	C
UAL	T	T	T	T						C	T		C	C
CS	T	T	T	T						C	T		C	C

T - The default function can be changed using tabular functions and an MPMA Tnnnnmm input record.

C - The default function can be changed using constant values input on an MPMA Tnnnnmm record.

X - The default function cannot be changed through user input.

Note: A blank space indicates that no default is provided, but may be supplied by the user, although in some cases the property may not be used.

* See Section 1 for a full description of these properties.

The default specific enthalpy values are computed by linear interpolation of the tabulated values listed below. The tabular values were computed by integrating the tables of specific heat capacities from Section 4. The latent heat of fusion from Section 10 was added at the melting point given in Section 9 over a range of 0.01 K.

2.1 Zircaloy

The default tabular values of specific enthalpy as a function of temperature for Zircaloy are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Zircaloy

Temperature	Specific Enthalpy (J/kg)
300.0	0.0
400.0	21915.0
640.0	105110.0
1090.0	263960.0
1093.0	265275.5
1113.0	276195.5
1133.0	288245.5
1153.0	301585.5
1173.0	316935.5
1193.0	332795.5
1213.0	346685.5
1233.0	357565.5
1248.0	363753.0
2098.0	666353.0
2098.01	891353.0
3598.0	1425353.0

2.2 Zirconium Oxide

The default tabular values of specific enthalpy as a function of temperature for zirconium oxide are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Zirconium Oxide

Temperature (K)	Specific Enthalpy (J/kg)
300.0	0.0
2990.0	1464167.0
2990.01	2171167.0
3500.0	2448760.0

2.3 Uranium Dioxide

The default tabular values of specific enthalpy as a function of temperature for uranium dioxide are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Uranium Dioxide

Temperature (K)	Specific Enthalpy (J/kg)
300.0	33143.0
400.0	58419.0
500.0	85883.0
600.0	114638.0

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Uranium Dioxide

Temperature (K) Specific Enthalpy (J/kg)

700.0	144257.0
800.0	174517.0
900.0	205288.0
1000.0	236492.0
1100.0	268080.0
1200.0	300023.0
1300.0	332309.0
1400.0	364947.0
1500.0	397973.0
1600.0	431455.0
1700.0	465502.0
1800.0	500266.0
1900.0	535945.0
2000.0	572782.0
2100.0	611064.0
2200.0	651111.0
2300.0	693275.0
2400.0	737927.0
2500.0	785450.0
2600.0	836232.0
2700.0	890656.0
2800.0	949096.0
2900.0	1011906.0
3000.0	1079422.0
3113.0	1161764.0
3113.01	1435764.0
3513.0	1636964.0

2.4 Stainless Steel

The default tabular values of specific enthalpy as a function of temperature for stainless steel are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Stainless Steel

Temperature (K) Specific Enthalpy (J/kg)

300.0	0.0
400.0	48926.0
500.0	99624.0
600.0	152092.0
700.0	206332.0
800.0	262343.0

Stainless Steel

Temperature (K)	Specific Enthalpy (J/kg)
-----------------	--------------------------

900.0	320125.0
1000.0	379679.0
1100.0	441003.0
1200.0	504099.0
1300.0	568966.0
1400.0	635604.0
1500.0	704014.0
1600.0	774194.0
1700.0	846146.0
1700.01	1114146.0
1800.0	1186986.0
3800.0	2643786.0

2.5 Stainless Steel Oxide

The default tabular values of specific enthalpy as a function of temperature for stainless steel oxide are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Stainless Steel Oxide

Temperature (K)	Specific Enthalpy (J/kg)
-----------------	--------------------------

300.0	0.0
1870.0	785000.0
1870.01	1383000.0
3500.0	2198000.0

2.6 Boron Carbide

The default tabular values of specific enthalpy as a function of temperature for boron carbide are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Boron Carbide

Temperature (K)	Specific Enthalpy (J/kg)
-----------------	--------------------------

300.0	0.0
2620.0	1160000.0
2620.01	1660000.0
3500.0	2100000.0

2.7 Silver-Indium-Cadmium

The default tabular values of specific enthalpy as a function of temperature for silver-indium-cadmium are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Silver-Indium-Cadmium

Temperature (K) Specific Enthalpy (J/kg)

300.0	0.0
400.0	21759.0
500.0	44031.0
600.0	66801.0
700.0	90091.0
800.0	113890.0
900.0	138200.0
1000.0	163010.0
1075.0	211000.0
1075.01	309000.0
1100.0	315350.0
5000.0	1306600.0

2.8 Uranium Metal

The default tabular values of specific enthalpy as a function of temperature for uranium metal are listed below. Linear extrapolation is allowed from the lower end of the tabulated range. No extrapolation is allowed from the upper end of the tabulated range.

Uranium Metal

Temperature (K) Specific Enthalpy (J/kg)

300.0	0.0
400.0	12050.0
600.0	39150.0
800.0	71350.0
1000.0	106950.0
1200.0	141050.0
1406.0	172259.0
1406.01	222499.0
5000.0	732847.0

2.9 Graphite

The default tabular values of specific enthalpy as a function of temperature for Graphite are listed below. Linear extrapolation is allowed from the lower end of the tabulated range. No extrapolation is allowed from the upper end of the tabulated range.

Graphite

Temperature (K)	Specific Enthalpy (J/kg)
-----------------	--------------------------

300.0	0.0
773.0	547910.0
1273.0	1414010.0
1773.0	2381110.0
2273.0	3405060.0
2773.0	4464560.0
3866.0	6879871.0
5000.0	9456545.0

2.10 Aluminum

The default tabular values of specific enthalpy as a function of temperature for aluminum are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Aluminum

Temperature (K)	Specific Enthalpy (J/kg)
-----------------	--------------------------

273.15	0.00
313.15	36056.00
353.15	72822.00
393.15	110304.00
433.15	148506.00
473.15	187432.00
513.15	227088.00
553.15	267464.00
593.15	308580.00
633.15	350458.00
673.15	393086.00
713.15	436470.00
753.15	480616.00
793.15	525528.00
833.15	571210.00
873.15	617668.00
913.15	664908.00
933.00	688643.00
933.01	1086443.00
1000.00	1165269.00
1500.00	1753519.00
2000.00	2341769.00

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2.11 Aluminum Oxide

The default tabular values of specific enthalpy as a function of temperature for aluminum oxide are listed below. Linear extrapolation is allowed from both ends of the tabular range.

Aluminum Oxide

Temperature (K) Specific Enthalpy (J/kg)

273.15	0.0
298.0	19243.0
350.0	62146.0
400.0	107619.0
500.0	206437.0
600.0	312785.0
800.0	540165.0
1000.0	780637.0
1500.0	1410855.0
2327.0	2518696.0
2327.01	3588710.0
5000.0	7386414.0

2.12 Cadmium

The default tabular values of specific enthalpy as a function of temperature for cadmium are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Cadmium

Temperature (K) Specific Enthalpy (J/kg)

298.15	0.00
400.00	24093.00
500.00	48813.00
594.00	73079.00
594.01	128347.00
600.00	129933.00
700.00	156373.00
800.00	182813.00
900.00	209253.00
1000.00	235693.00
1040.00	246269.00

2.13 Stainless Steel 304

The default tabular values of specific enthalpy as a function of temperature for stainless steel 304 are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Stainless Steel 304

Temperature (K) Specific Enthalpy (J/kg)

300.00	0.00
400.00	52005.00
500.00	105370.00
600.00	160085.00
700.00	216155.00
800.00	273585.00
900.00	332375.00
1000.00	392520.00
1100.00	454020.00
1200.00	516880.00
1300.00	581095.00
1400.00	646665.00
1500.00	713630.00
1600.00	781950.00
1700.00	851590.00
1700.01	1120790.00
1800.00	1200800.00
1900.00	1280810.00
2000.00	1360820.00
2500.00	1760870.00
3000.00	2160920.00

2.14 Lithium Aluminum

The default tabular values of specific enthalpy as a function of temperature for lithium aluminum are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Lithium Aluminum

Temperature (K) Specific Enthalpy (J/kg)

298.15	0.00
313.15	14357.00
353.15	53199.00
393.15	92877.00
433.15	133411.00
473.15	174815.00
513.15	217007.00
533.15	259879.00
593.15	303449.00
633.15	347739.00
673.15	392737.00
713.15	438455.00

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Lithium Aluminum

Temperature (K) Specific Enthalpy (J/kg)

753.15	484913.00
793.15	532121.00
833.15	580081.00
873.15	628799.00
917.00	683118.00
917.01	1081568.00
1000.00	1183866.00
1100.00	1307111.00
1200.00	1430341.00

2.15 Uranium Aluminum

The default tabular values of specific enthalpy as a function of temperature for uranium aluminum are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Uranium Aluminum

Temperature (K) Specific Enthalpy (J/kg)

293.15	0.00
333.15	26818.00
373.15	54172.00
413.15	82068.00
453.15	110512.00
493.15	139512.00
533.15	169072.00
573.15	199198.00
613.15	229900.00
653.15	261184.00
693.15	293056.00
733.15	325524.00
773.15	358596.00
813.15	392278.00
853.15	426578.00
893.15	461506.00
919.00	484411.00
919.01	484421.00
962.00	522131.00
1039.00	589676.00
1123.00	663125.00
1128.50	667919.00
1128.51	957919.00
1223.00	1040285.00

Uranium Aluminum

Temperature (K)	Specific Enthalpy (J/kg)
-----------------	--------------------------

1305.00	1111757.00
1338.00	1140519.00
1500.00	1281719.00
2000.00	1717519.00

2.16 Carbon Steel

The default tabular values of specific enthalpy as a function of temperature for carbon steel are listed below. Linear extrapolation is allowed from both ends of the tabulated range.

Carbon Steel

Temperature (K)	Specific Enthalpy (J/kg)
-----------------	--------------------------

273.15	0.0
373.15	45667.0
473.15	95490.8
573.15	149471.4
673.15	207608.3
773.15	271000.8
873.15	341966.8
923.15	381218.1
973.15	424656.3
1023.15	475944.8
1033.15	488295.9
1073.15	531838.7
1123.15	571090.0
1223.15	642265.5
1349.82	729771.6
1373.15	745920.6
1473.15	815868.4
1573.15	886996.6
1673.15	959305.2
1773.15	1032794.1
1810.90	1060843.1
1810.91	1332803.1
5000.00	3709472.4

3. Temperature as a Function of Special Enthalpy

The temperature as a function of specific enthalpy may be computed from either a user-specified tabular function or a MELCOR default table.

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The user-specified tabular function to define a new material or to override the default table for an existing material is invoked by using a standard tabular function (see the TF Package Users' Guide) to input the temperature (K) as a function of enthalpy (J/kg). Currently, there are no checks made on the consistency of user-input values for enthalpy, specific heat capacity, melting temperature, and latent heat of fusion; this could be rectified in future code versions.

The following materials have default tables for temperature as a function of enthalpy:

Zircaloy	Boron Carbide	Aluminum Oxide
Zirconium Oxide	Silver-Indium-Cadmium	Cadmium
Uranium Dioxide	Uranium Metal	Stainless Steel 304
Stainless Steel	Graphite	Lithium Aluminum
Stainless Steel Oxide	Aluminum	Uranium Aluminum
Carbon Steel		

The default specific enthalpy values are calculated by linear interpolation of tabulated values computed by inverting the tables of specific enthalpy as a function of temperature from Section 2. Extrapolation rules are the same as those listed in Section 2.

4. Specific Heat Capacity as a Function of Temperature

The specific heat capacity at constant pressure may be computed from either a user-specified tabular function or a MELCOR default table defined in subroutine MPDFVL.

The user-specified tabular function to define a new material or to override the default table for an existing material is invoked by using a standard tabular function (see the TF Package Users' Guide) to input the specific heat capacity (J/kg-K) as a function of temperature (K). There are no checks made on the consistency of user-input values for enthalpy, specific heat capacity, melting temperature, and latent heat of fusion.

The following materials have default tables for specific heat capacity:

Zircaloy	Concrete
Zirconium Oxide	Aluminum
Uranium Dioxide	Aluminum Oxide
Stainless Steel	Cadmium
Stainless Steel Oxide	Stainless Steel 304
Boron Carbide	Lithium Aluminum
Silver-Indium-Cadmium	Uranium Aluminum
Uranium Metal	Carbon Steel
Graphite	

The default specific heat capacity values are computed by linear interpolation of the tabulated values listed below. Data sources are given with each table.

4.1 Zircaloy

The default tabular values of specific heat capacity as a function of temperature for Zircaloy are listed below. No extrapolation is allowed.

Zircaloy

Temp(K)	Specific Heat Capacity (J/kg-K)	Data Source
273.1	275.0	Ref. [1], extrapolated
400.0	302.0	Ref. [1]
640.0	331.0	Ref. [1]
1090.0	375.0	Ref. [1]
1093.0	502.0	Ref. [1]
1113.0	590.0	Ref. [1]
1133.0	615.0	Ref. [1]
1153.0	719.0	Ref. [1]
1173.0	816.0	Ref. [1]
1193.0	770.0	Ref. [1]
1213.0	619.0	Ref. [1]
1233.0	469.0	Ref. [1]
1248.0	356.0	Ref. [1]
2098.0	356.0	Ref. [1]
5000.0	356.0	Ref. [1], extrapolated

4.2 Zirconium Oxide

The default tabular values of specific heat capacity as a function of temperature for zirconium oxide are listed below. No extrapolation is allowed.

Zirconium Oxide

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	544.3	Ref. [1]
5000.0	544.3	Ref. [1]

4.3 Uranium Dioxide

The default tabular values of specific heat capacity as a function of temperature for uranium dioxide are listed below. No extrapolation is allowed.

Uranium Dioxide

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	230.22	Ref. [1], extrapolated

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Uranium Dioxide

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
400.0	265.84	Ref. [1]
500.0	282.07	Ref. [1]
600.0	292.36	Ref. [1]
700.0	299.67	Ref. [1]
800.0	305.31	Ref. [1]
900.0	309.98	Ref. [1]
1000.0	314.03	Ref. [1]
1100.0	317.69	Ref. [1]
1200.0	321.15	Ref. [1]
1300.0	324.59	Ref. [1]
1400.0	328.24	Ref. [1]
1500.0	332.40	Ref. [1]
1600.0	337.43	Ref. [1]
1700.0	343.76	Ref. [1]
1800.0	351.84	Ref. [1]
1900.0	362.14	Ref. [1]
2000.0	375.09	Ref. [1]
2100.0	391.08	Ref. [1]
2200.0	410.45	Ref. [1]
2300.0	433.45	Ref. [1]
2400.0	460.23	Ref. [1]
2500.0	490.88	Ref. [1]
2600.0	525.40	Ref. [1]
2700.0	563.71	Ref. [1]
2800.0	605.67	Ref. [1]
2900.0	651.09	Ref. [1]
3000.0	699.73	Ref. [1]
3113.0	758.23	Ref. [1]
3113.01	503.0	Ref. [1]
5000.0	503.0	Ref. [1], extrapolated

4.4 Stainless Steel

The default tabular values of specific heat capacity as a function of temperature for 347 stainless steel are listed below. No extrapolation is allowed.

Stainless Steel

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	475.6	Ref. [1], extrapolated
400.0	498.1	Ref. [1]
500.0	515.8	Ref. [1]
600.0	533.5	Ref. [1]

Stainless Steel

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
700.0	551.3	Ref. [1]
800.0	569.0	Ref. [1]
900.0	586.7	Ref. [1]
1000.0	604.4	Ref. [1]
1100.0	622.1	Ref. [1]
1200.0	639.8	Ref. [1]
1300.0	657.5	Ref. [1]
1400.0	675.2	Ref. [1]
1500.0	693.0	Ref. [1]
1600.0	710.7	Ref. [1]
1700.0	728.4	Ref. [1]
1700.01	728.4	Ref. [1]
1800.0	728.4	Ref. [1]
5000.0	728.4	Ref. [1], extrapolated

4.5 Stainless Steel Oxide

The default tabular values of specific heat capacity as a function of temperature for stainless steel oxide are listed below. No extrapolation is allowed.

Stainless Steel Oxide

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	500.0	Estimated
5000.0	500.0	Estimated

4.6 Boron Carbide

The default tabular values of specific heat capacity as a function of temperature for boron carbide are listed below. No extrapolation is allowed.

Boron Carbide

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	500.0	Estimated
5000.0	500.0	Estimated

4.7 Silver-Indium-Cadmium

The default tabular values of specific heat capacity as a function of temperature for silver-indium-cadmium are listed below. Linear extrapolation below 300 K is permitted.

Silver-Indium-Cadmium

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
300.0	215.04	Ref. [2]

Silver-Indium-Cadmium

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
400.0	220.14	Ref. [2]
500.0	225.23	Ref. [2]
600.0	230.33	Ref. [2]
700.0	235.42	Ref. [2]
800.0	240.52	Ref. [2]
900.0	245.61	Ref. [2]
1000.0	250.71	Ref. [2]
1075.0	254.15	Ref. [2]
5000.0	254.15	Ref. [2]

4.8 Uranium Metal

The default tabular values of specific heat capacity as a function of temperature for uranium metal are listed below. No extrapolation is allowed.

Uranium Metal

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	113.6	Ref. [3], p. 758, extrapolated
300.0	116.0	Ref. [3], p. 758
400.0	125.0	Ref. [3], p. 758
600.0	146.0	Ref. [3], p. 758
800.0	176.0	Ref. [3], p. 758
1000.0	180.0	Ref. [3], p. 758
1200.0	161.0	Ref. [3], p. 758
1406.0	142.0	Ref. [3], p. 758, extrapolated
5000.0	142.0	Constant from melting point of 1406 K

4.9 Graphite

The default tabular values of specific heat capacity as a function of temperature for graphite are listed below. No extrapolation is allowed.

Graphite

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	665.16	Ref. [4], p. 180, generic graphite, extrapolated
298.0	711.7	Ref. [4], p. 180, generic graphite
773.0	1601.3	Ref. [4], p. 180, generic graphite
1273.0	1863.0	Ref. [4], p. 180, generic graphite
1773.0	2005.3	Ref. [4], p. 180, generic graphite
2273.0	2090.6	Ref. [4], p. 180, generic graphite
2773.0	2147.5	Ref. [4], p. 180, generic graphite

Graphite

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
3866.0	2272.0	Ref. [4], p. 180, generic graphite, extrapolated
5000.0	2272.0	Constant from melting point of 3866 K

4.10 Concrete

The default tabular values of specific heat capacity as a function of temperature for concrete are listed below. No extrapolation is allowed.

Concrete

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	837.3	Ref. [5], p. 635, stone concrete @ 294 K
5000.0	837.3	Ref. [5], p. 635, stone concrete @ 294 K

4.11 Aluminum

The default tabular values of specific heat capacity as a function of temperature for aluminum are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Aluminum

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	892.60	Ref. [6]
313.15	910.20	Ref. [6]
353.15	928.10	Ref. [6]
393.15	946.00	Ref. [6]
433.15	964.10	Ref. [6]
473.15	982.20	Ref. [6]
513.15	1000.60	Ref. [6]
553.15	1018.20	Ref. [6]
593.15	1037.60	Ref. [6]
633.15	1056.30	Ref. [6]
673.15	1075.10	Ref. [6]
713.15	1094.10	Ref. [6]
753.15	1113.20	Ref. [6]
793.15	1132.40	Ref. [6]
833.15	1151.70	Ref. [6]
873.15	1171.20	Ref. [6]
913.15	1190.80	Ref. [6]
933.00	1200.60	Ref. [6]
933.01	1176.50	Ref. [6]

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Aluminum

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
1000.00	1176.50	Ref. [6]
1500.00	1176.50	Ref. [6]
2000.00	1176.50	Ref. [6]

4.12 Aluminum Oxide

The default tabular values of specific heat capacity as a function of temperature for aluminum oxide are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Aluminum Oxide

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	774.38	Ref. [7]
298.0	774.38	Ref. [7]
350.0	875.73	Ref. [7]
400.0	943.20	Ref. [7]
500.0	1033.16	Ref. [7]
600.0	1093.80	Ref. [7]
800.0	1180.00	Ref. [7]
1000.0	1224.72	Ref. [7]
1500.0	1296.15	Ref. [7]
2327.0	1383.03	Ref. [7]
2327.01	1420.77	Ref. [7]
5000.0	1420.77	Ref. [7]

4.13 Cadmium

The default tabular values of specific heat capacity as a function of temperature for cadmium are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Cadmium

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
298.15	231.30	Ref. [6]
400.00	241.80	Ref. [6]
500.00	252.60	Ref. [6]
594.00	263.70	Ref. [6]
594.01	264.40	Ref. [6]
600.00	264.40	Ref. [6]
1040.00	264.40	Ref. [6]

4.14 Stainless Steel 304

The default tabular values of specific heat capacity as a function of temperature for stainless steel 304 are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Stainless Steel 304

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
300.00	513.20	Ref. [6]
400.00	526.90	Ref. [6]
500.00	540.40	Ref. [6]
600.00	553.90	Ref. [6]
700.00	567.50	Ref. [6]
800.00	581.10	Ref. [6]
900.00	594.70	Ref. [6]
1000.00	608.20	Ref. [6]
1100.00	621.80	Ref. [6]
1200.00	635.40	Ref. [6]
1300.00	648.90	Ref. [6]
1400.00	662.50	Ref. [6]
1500.00	676.80	Ref. [6]
1600.00	689.60	Ref. [6]
1700.00	703.20	Ref. [6]
1700.01	800.10	Ref. [6]
1800.00	800.10	Ref. [6]
3000.00	800.10	Ref. [6]

4.15 Lithium Aluminum

The default tabular values of specific heat capacity as a function of temperature for lithium aluminum are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Lithium Aluminum

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
298.15	953.50	Ref. [6]
313.15	960.80	Ref. [6]
353.15	981.30	Ref. [6]
393.15	1002.60	Ref. [6]
433.15	1024.10	Ref. [6]
473.15	1046.10	Ref. [6]
513.10*	1063.50	Ref. [6]
553.15	1080.10	Ref. [6]
593.15	1098.40	Ref. [6]

Lithium Aluminum

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
633.15	1116.10	Ref. [6]
673.15	1133.80	Ref. [6]
713.15	1152.10	Ref. [6]
753.15	1170.80	Ref. [6]
793.15	1189.60	Ref. [6]
833.15	1208.40	Ref. [6]
873.15	1227.50	Ref. [6]
917.00	1250.00	Ref. [6]
917.01	1232.50	Ref. [6]
1000.00	1232.50	Ref. [6]
1100.00	1232.40	Ref. [6]
1200.00	1232.20	Ref. [6]

* Value differs slightly from reference. MELCOR/SR-Mod3 Fortran value is used.

4.16 Uranium Aluminum

The default tabular values of specific heat capacity as a function of temperature for uranium aluminum are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Uranium Aluminum

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
293.15	663.80	Ref. [6]
333.15	677.10	Ref. [6]
373.15	690.60	Ref. [6]
413.15	704.20	Ref. [6]
453.15	718.00	Ref. [6]
493.15	732.00	Ref. [6]
533.15	746.00	Ref. [6]
573.15	760.30	Ref. [6]
613.15	774.80	Ref. [6]
653.15	789.40	Ref. [6]
693.15	804.20	Ref. [6]
733.15	819.20	Ref. [6]
773.15	834.40	Ref. [6]
813.15	849.70	Ref. [6]
853.15	865.30	Ref. [6]
893.15	881.10	Ref. [6]
919.00	891.10	Ref. [6]
919.01	877.20	Ref. [6]
962.00	877.20	Ref. [6]

Uranium Aluminum

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
1039.00	877.20	Ref. [6]
1123.00	871.60	Ref. [6]
1223.00	871.60	Ref. [6]
1305.00	871.60	Ref. [6]
1338.00	871.60	Ref. [6]
1500.00	871.60	Ref. [6]

4.17 Carbon Steel

The default tabular values of specific heat capacity as a function of temperature for carbon steel are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Carbon Steel

Temp (K)	Specific Heat Capacity (J/kg-K)	Data Source
273.15	435.89	Ref. [8]
373.15	477.45	Ref. [8]
473.15	519.02	Ref. [8]
573.15	560.59	Ref. [8]
673.15	602.15	Ref. [8]
773.15	665.70	Ref. [8]
873.15	753.62	Ref. [8]
923.15	816.43	Ref. [8]
973.15	921.10	Ref. [8]
1023.15	1130.44	Ref. [8]
1033.15	1339.78	Ref. [8]
1073.15	837.36	Ref. [8]
1123.15	732.69	Ref. [8]
1223.15	690.82	Ref. [8]
1349.82	690.82	Ref. [8]
1373.15	693.58	Ref. [8]
1473.15	705.38	Ref. [8]
1573.15	717.18	Ref. [8]
1673.15	728.99	Ref. [8]
1773.15	740.79	Ref. [8]
1810.90	745.25	Ref. [8]
1810.91	745.25	Ref. [8]
5000.00	745.25	Ref. [8]

5. Thermal Conductivity as a Function of Temperature

The thermal conductivity may be computed from two different methods. One method, used for structural materials in the COR and HS packages, utilizes tabular data which may be either a user-specified tabular function or a MELCOR default table. The other method, used for noncondensable gases and optionally for steam and air, utilizes the Eucken correlation for single, low-pressure gases and the Wassijewa equation for a combination of gases.

5.1 Tabular

The user-specified tabular function to define a new material or to override the default table for an existing material is invoked by using a standard tabular function to input the thermal conductivity (W/m-K) as a function of temperature (K).

The following materials have default tables for thermal conductivity:

Water	Uranium Dioxide	Uranium Metal	Cadmium
Steam	Stainless Steel	Graphite	Stainless Steel 304
Air	Stainless Steel Oxide	Concrete	Lithium Aluminum
Zircaloy	Boron Carbide	Aluminum	Uranium Aluminum
Zirconium Oxide	Silver-Indium-Cadmium	Aluminum Oxide	Carbon Steel

The default thermal conductivity values are computed by linear interpolation of the tabulated values listed below. Data sources are given with each table.

5.1.1 Water

The default tabular values of thermal conductivity as a function of temperature for liquid water are listed below. No extrapolation is allowed.

Water

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
255.37	0.551	Ref. [9]
273.15	0.569	Ref. [9]
283.15	0.586	Ref. [9]
293.15	0.602	Ref. [9]
303.15	0.617	Ref. [9]
313.15	0.630	Ref. [9]
323.15	0.643	Ref. [9]
333.15	0.653	Ref. [9]
343.15	0.662	Ref. [9]
353.15	0.669	Ref. [9]

Water

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
363.15	0.675	Ref. [9]
373.15	0.680	Ref. [9]
383.15	0.683	Ref. [9]
393.15	0.685	Ref. [9]
403.15	0.687	Ref. [9]
413.15	0.687	Ref. [9]
423.15	0.686	Ref. [9]
433.15	0.684	Ref. [9]
443.15	0.681	Ref. [9]
453.15	0.676	Ref. [9]
463.15	0.671	Ref. [9]
473.15	0.664	Ref. [9]
483.15	0.657	Ref. [9]
493.15	0.648	Ref. [9]
503.15	0.639	Ref. [9]
513.15	0.629	Ref. [9]
523.15	0.617	Ref. [9]
533.15	0.604	Ref. [9]
543.15	0.589	Ref. [9]
553.15	0.573	Ref. [9]
563.15	0.557	Ref. [9]
573.15	0.540	Ref. [9]
583.15	0.522	Ref. [9]
593.15	0.503	Ref. [9]
603.15	0.482	Ref. [9]
613.15	0.460	Ref. [9]
623.15	0.435	Ref. [9]
633.15	0.401	Ref. [9]
647.245	0.318	Ref. [9], extrapolated to critical point

5.1.2 Steam

The default tabular values of thermal conductivity as a function of temperature for steam are listed below. Constant extrapolation is allowed from the upper end of the tabulated range. No extrapolation is allowed from the lower end of the tabulated range.

Steam

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
255.37	0.0144	Ref. [9]
273.15	0.0176	Ref. [9]
293.15	0.0188	Ref. [9]
313.15	0.0201	Ref. [9]

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Steam

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
333.15	0.0216	Ref. [9]
353.15	0.0231	Ref. [9]
373.15	0.0245	Ref. [9]
393.15	0.0260	Ref. [9]
413.15	0.0277	Ref. [9]
433.15	0.0295	Ref. [9]
453.15	0.0313	Ref. [9]
473.15	0.0331	Ref. [9]
493.15	0.0351	Ref. [9]
513.15	0.0371	Ref. [9]
533.15	0.0391	Ref. [9]
553.15	0.0412	Ref. [9]
573.15	0.0433	Ref. [9]
593.15	0.0455	Ref. [9]
613.15	0.0478	Ref. [9]
633.15	0.0501	Ref. [9]
653.15	0.0525	Ref. [9]
673.15	0.0548	Ref. [9]
693.15	0.0573	Ref. [9]
713.15	0.0597	Ref. [9]
733.15	0.0622	Ref. [9]
753.15	0.0648	Ref. [9]
773.15	0.0673	Ref. [9]
793.15	0.0699	Ref. [9]
813.15	0.0725	Ref. [9]
833.15	0.0752	Ref. [9]
853.15	0.0778	Ref. [9]
873.15	0.0805	Ref. [9]
893.15	0.0832	Ref. [9]
913.15	0.0859	Ref. [9]
933.15	0.0887	Ref. [9]
953.15	0.0914	Ref. [9]
973.15	0.0942	Ref. [9]
993.15	0.0970	Ref. [9]
1013.15	0.0998	Ref. [9]
1033.15	0.1026	Ref. [9]
1053.15	0.1054	Ref. [9]
1073.15	0.1081	Ref. [9]
1200.00	0.130	Ref. [9]
1400.00	0.187	Ref. [9]
1600.00	0.219	Ref. [9]

Steam

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
1800.00	0.263	Ref. [9]
2000.00	0.333	Ref. [9]
2200.00	0.459	Ref. [9]
2400.00	0.690	Ref. [9]
2600.00	1.110	Ref. [9]
2800.00	1.820	Ref. [9]
3000.00	2.940	Ref. [9]
3200.00	4.495	Ref. [9]
3400.00	6.625	Ref. [9]
3600.00	7.610	Ref. [9]
3800.00	7.765	Ref. [9]
4000.00	7.280	Ref. [9]

5.1.3 Air

The default tabular values of thermal conductivity as a function of temperature for air are listed below. Linear extrapolation is allowed from the upper end of the tabulated range. No extrapolation is allowed from the lower end of the tabulated range.

Air

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
255.370	0.0227081	Ref. [10]
310.926	0.0270005	Ref. [10]
366.482	0.0311544	Ref. [10]
422.038	0.0360006	Ref. [10]
477.594	0.0399815	Ref. [10]
533.150	0.0425777	Ref. [10]
588.706	0.0458662	Ref. [10]
644.262	0.0491547	Ref. [10]
699.818	0.0524432	Ref. [10]
755.374	0.0553856	Ref. [10]
810.930	0.0583280	Ref. [10]
866.486	0.0610972	Ref. [10]
922.042	0.0638665	Ref. [10]
977.598	0.0664627	Ref. [10]
1033.154	0.0690589	Ref. [10]
1088.710	0.0718282	Ref. [10]
1144.266	0.0740782	Ref. [10]
1199.822	0.0763283	Ref. [10]
1255.378	0.0785783	Ref. [10]
1310.934	0.0808284	Ref. [10]
1366.490	0.0830784	Ref. [10]

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Air

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
1422.046	0.0853284	Ref. [10]
1477.602	0.0874054	Ref. [10]
1533.158	0.0896554	Ref. [10]
1588.714	0.0920786	Ref. [10]
1644.270	0.0941555	Ref. [10]
1699.826	0.0960594	Ref. [10]
1755.382	0.0979633	Ref. [10]
1810.938	0.0998672	Ref. [10]
1866.494	0.101425	Ref. [10]
1922.050	0.103156	Ref. [10]
1977.606	0.105060	Ref. [10]
2033.162	0.107137	Ref. [10]
2088.718	0.209040	Ref. [10]
2144.274	0.110425	Ref. [10]
2199.830	0.111810	Ref. [10]
2255.386	0.113367	Ref. [10]
2310.942	0.115098	Ref. [10]
2366.498	0.116829	Ref. [10]
2422.054	0.113367	Ref. [10]
2477.610	0.120118	Ref. [10]
2533.166	0.121675	Ref. [10]

5.1.4 Zircaloy

The default tabular values of thermal conductivity as a function of temperature for Zircaloy are listed below. No extrapolation is allowed.

Zircaloy

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	12.1	Ref. [1], p. 218, formula
293.2	12.6	Ref. [1], p. 221, Zircaloy-2
473.2	14.5	Ref. [1], p. 221, Zircaloy-2
673.2	17.0	Ref. [1], p. 221, Zircaloy-2
873.2	19.9	Ref. [1], p. 221, Zircaloy-2
1073.2	23.1	Ref. [1], p. 221, Zircaloy-2
1269.2	26.2	Ref. [1], p. 219, Zircaloy-4
1508.2	31.7	Ref. [1], p. 219, Zircaloy-4
1624.2	36.3	Ref. [1], p. 219, Zircaloy-4
1771.2	41.8	Ref. [1], p. 219, Zircaloy-4
2098.2	58.4	Ref. [1], p. 218, formula
5000.0	58.4	Constant beyond melting point of 2098 K

5.1.5 Zirconium Oxide

The default tabular values of thermal conductivity as a function of temperature for zirconium oxide are listed below. No extrapolation is allowed.

Zirconium Oxide

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	1.94	Ref. [1], p. 224, formula
500.0	1.98	Ref. [1], p. 224, formula
750.0	2.06	Ref. [1], p. 224, formula
1000.0	2.17	Ref. [1], p. 224, formula
1250.0	2.28	Ref. [1], p. 224, formula
1500.0	2.39	Ref. [1], p. 224, formula
2000.0	2.49	Ref. [1], p. 224, formula
5000.0	2.49	Constant beyond 2000 K

5.1.6 Uranium Dioxide

The default tabular values of thermal conductivity as a function of temperature for uranium dioxide are listed below. No extrapolation is allowed.

Uranium Dioxide

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	9.24	Ref. [11], p. 104, extrapolated
366.3	7.79	Ref. [11], p. 104
539.0	6.53	Ref. [1], p. 30
757.0	4.92	Ref. [1], p. 30
995.0	3.87	Ref. [1], p. 30
1182.0	3.20	Ref. [1], p. 30
1490.0	2.53	Ref. [1], p. 30
1779.0	2.19	Ref. [1], p. 30
1975.0	2.17	Ref. [1], p. 30
2181.0	2.25	Ref. [1], p. 30
2373.0	2.56	Ref. [1], p. 30
2577.0	2.80	Ref. [1], p. 35
2773.0	3.15	Ref. [1], p. 35
3026.0	3.75	Ref. [1], p. 35
3113.0	3.96	Ref. [1], p. 35, extrapolated
5000.0	3.96	Constant beyond melting point of 3113 K

5.1.7 Stainless Steel (SS)

The default tabular values of thermal conductivity as a function of temperature for stainless steel (SS), type 347, are listed below. No extrapolation is allowed.

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Stainless Steel (SS)

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	13.8	Ref. [3], p. 757, extrapolated
400.0	15.8	Ref. [3], p. 757
600.0	18.9	Ref. [3], p. 757
800.0	21.9	Ref. [3], p. 757
1000.0	24.7	Ref. [3], p. 757
1700.0	34.5	Ref. [3], p. 757, extrapolated
5000.0	34.5	Constant beyond melting point of 1700 K

5.1.8 Stainless Steel Oxide

The default tabular values of thermal conductivity as a function of temperature for stainless steel oxide are listed below.

Stainless Steel Oxide

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	20.0	Estimated
5000.0	20.0	Estimated

5.1.9 Boron Carbide

The default tabular values of thermal conductivity as a function of temperature for boron carbide are listed below. No extrapolation is allowed.

Boron Carbide

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	2.0	Estimated
5000.0	2.0	Estimated

5.1.10 Silver-Indium-Cadmium

The default tabular values of thermal conductivity as a function of temperature for silver-indium-cadmium are listed below. No extrapolation is allowed.

Silver-Indium-Cadmium

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
300.0	57.088	Ref. [2]
400.0	64.992	Ref. [2]
500.0	72.010	Ref. [2]
600.0	78.140	Ref. [2]
700.0	83.384	Ref. [2]
800.0	87.740	Ref. [2]
900.0	91.208	Ref. [2]
1000.0	93.790	Ref. [2]

Silver-Indium-Cadmium

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
1050.0	94.748	Ref. [2]
1075.0	48.000	Ref. [2]
5000.0	48.000	Ref. [2]

5.1.11 Uranium Metal

The default tabular values of thermal conductivity as a function of temperature for uranium metal are listed below. No extrapolation is allowed.

Uranium Metal

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	24.31	Ref. [11], p. 104, extrapolated
298.0	25.12	Ref. [11], p. 104
366.3	27.34	Ref. [11], p. 104
421.9	28.38	Ref. [11], p. 104
477.4	29.34	Ref. [11], p. 104
533.0	30.28	Ref. [11], p. 104
588.6	31.32	Ref. [11], p. 104
644.1	32.22	Ref. [11], p. 104
699.7	33.22	Ref. [11], p. 104
755.2	34.09	Ref. [11], p. 104
810.8	35.04	Ref. [11], p. 104
866.3	35.90	Ref. [11], p. 104
921.9	36.68	Ref. [11], p. 104
977.4	37.37	Ref. [11], p. 104
1033.0	38.07	Ref. [11], p. 104
1406.0	42.77	Ref. [11], p. 104, extrapolated
5000.0	42.77	Constant beyond melting point of 1406

5.1.12 Graphite

The default tabular values of thermal conductivity as a function of temperature for graphite are listed below. No extrapolation is allowed.

Graphite

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	35.55	Ref. [12], irradiated graphite
5000.0	35.55	Ref. [12], irradiated graphite

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5.1.13 Concrete

The default tabular values of thermal conductivity as a function of temperature for concrete are listed below. No extrapolation is allowed.

Concrete

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	0.9344	Ref. [5], p. 635, stone concrete @ 294 K
5000.0	0.9344	Ref. [5], p. 635, stone concrete @ 294 K

5.1.14 Aluminum

The default tabular values of thermal conductivity as a function of temperature for aluminum are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Aluminum

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	236.00	Ref. [6]
300.00	237.00	Ref. [6]
350.00	240.00	Ref. [6]
400.00	240.00	Ref. [6]
500.00	237.00	Ref. [6]
600.00	232.00	Ref. [6]
700.00	226.00	Ref. [6]
800.00	220.00	Ref. [6]
900.00	213.00	Ref. [6]
933.00	211.00	Ref. [6]
933.01	90.70	Ref. [6]
1000.00	93.00	Ref. [6]
1100.00	96.40	Ref. [6]
1200.00	99.40	Ref. [6]
1300.00	102.00	Ref. [6]

5.1.15 Aluminum Oxide

The default tabular values of thermal conductivity as a function of temperature for aluminum oxide are listed below. Constant extrapolation is allowed from both ends of the tabular range.

Aluminum Oxide

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	18.73	Ref. [7]
300.0	17.27	Ref. [7]
350.0	15.12	Ref. [7]

Aluminum Oxide

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
400.0	13.47	Ref. [7]
500.0	11.11	Ref. [7]
600.0	9.49	Ref. [7]
700.0	8.31	Ref. [7]
800.0	7.41	Ref. [7]
900.0	6.69	Ref. [7]
1000.0	6.11	Ref. [7]
1200.0	5.22	Ref. [7]
1400.0	4.57	Ref. [7]
1600.0	4.07	Ref. [7]
1800.0	3.68	Ref. [7]
2000.0	3.36	Ref. [7]
2400.0	2.87	Ref. [7]
2800.0	2.51	Ref. [7]
3400.0	2.12	Ref. [7]
4200.0	1.77	Ref. [7]
5000.0	1.42	Ref. [7]

5.1.16 Cadmium

The default tabular values of thermal conductivity as a function of temperature for cadmium are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Cadmium

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	97.50	Ref. [6]
283.15	97.30	Ref. [6]
293.15	97.00	Ref. [6]
303.15	96.80	Ref. [6]
313.15	96.60	Ref. [6]
323.15	96.40	Ref. [6]
333.15	96.20	Ref. [6]
343.15	96.00	Ref. [6]
353.15	95.70	Ref. [6]
363.15	95.50	Ref. [6]
373.15	95.30	Ref. [6]
383.15	95.10	Ref. [6]
393.15	94.90	Ref. [6]
403.15	94.70	Ref. [6]
413.15	94.40	Ref. [6]
423.15	94.20	Ref. [6]
433.15	94.00	Ref. [6]

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Cadmium

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
443.15	93.70	Ref. [6]
453.15	93.50	Ref. [6]
463.15	93.20	Ref. [6]
473.15	92.90	Ref. [6]
483.15	92.60	Ref. [6]
493.15	92.30	Ref. [6]
503.15	91.90	Ref. [6]
513.15	91.60	Ref. [6]
523.15	91.20	Ref. [6]
533.15	90.80	Ref. [6]
543.15	90.40	Ref. [6]
553.15	89.90	Ref. [6]
563.15	89.40	Ref. [6]
573.15	88.90	Ref. [6]
583.15	88.40	Ref. [6]
594.00	87.90	Ref. [6]
594.01	41.60	Ref. [6]
600.00	42.00	Ref. [6]
700.00	49.00	Ref. [6]
800.00	55.90	Ref. [6]
1040.00	72.50	Ref. [6]

5.1.17 Stainless Steel 304

The default tabular values of thermal conductivity as a function of temperature for stainless steel 304 are listed below. Constant extrapolation is allowed from the lower end of the tabulated range. Linear extrapolation is allowed from the upper end of the tabulated range.

Stainless Steel 304

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
300.00	13.00	Ref. [6]
400.00	14.60	Ref. [6]
500.00	16.20	Ref. [6]
600.00	17.80	Ref. [6]
700.00	19.40	Ref. [6]
800.00	21.10	Ref. [6]
900.00	22.70	Ref. [6]
1000.00	24.30	Ref. [6]
1100.00	25.90	Ref. [6]
1200.00	27.50	Ref. [6]
1300.00	29.10	Ref. [6]
1400.00	30.80	Ref. [6]

Stainless Steel 304

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
1500.00	32.40	Ref. [6]
1600.00	34.00	Ref. [6]
1700.00	35.60	Ref. [6]
1700.01	17.80	Ref. [6]
1800.00	18.10	Ref. [6]
1900.00	18.50	Ref. [6]
2000.00	18.80	Ref. [6]
2100.00	19.10	Ref. [6]
2200.00	19.40	Ref. [6]
2300.00	19.80	Ref. [6]
2400.00	20.10	Ref. [6]
2500.00	20.40	Ref. [6]
2600.00	20.70	Ref. [6]
2700.00	21.10	Ref. [6]
2800.00	21.40	Ref. [6]
2900.00	21.70	Ref. [6]
3000.00	22.00	Ref. [6]

5.1.18 Lithium Aluminum

The default tabular values of thermal conductivity as a function of temperature for lithium aluminum are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Lithium Aluminum

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	236.00	Ref. [6], Aluminum value
300.00	237.00	Ref. [6], Aluminum value
350.00	240.00	Ref. [6], Aluminum value
400.00	240.00	Ref. [6], Aluminum value
500.00	237.00	Ref. [6], Aluminum value
600.00	232.00	Ref. [6], Aluminum value
700.00	226.00	Ref. [6], Aluminum value
800.00	220.00	Ref. [6], Aluminum value
900.00	213.00	Ref. [6], Aluminum value
933.00	211.00	Ref. [6], Aluminum value
933.01	90.70	Ref. [6], Aluminum value
1000.00	93.00	Ref. [6], Aluminum value
1100.00	96.40	Ref. [6], Aluminum value
1200.00	99.40	Ref. [6], Aluminum value
1300.00	102.00	Ref. [6], Aluminum value

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5.1.19 Uranium Aluminum

The default tabular values of thermal conductivity as a function of temperature for uranium aluminum are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Uranium Aluminum

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
293.15	142.60	Ref. [6]
333.15	144.90	Ref. [6]
373.15	146.80	Ref. [6]
413.15	148.20	Ref. [6]
453.15	149.20	Ref. [6]
493.15	149.70	Ref. [6]
533.15	149.80	Ref. [6]
573.15	149.50	Ref. [6]
613.15	148.80	Ref. [6]
653.15	147.50	Ref. [6]
693.15	145.90	Ref. [6]
733.15	143.80	Ref. [6]
773.15	141.30	Ref. [6]
813.15	138.30	Ref. [6]
853.15	134.90	Ref. [6]
893.15	131.10	Ref. [6]
919.00	128.40	Ref. [6]
919.01	96.60	Ref. [6]
962.00	96.60	Ref. [6]
1039.00	97.00	Ref. [6]
1123.00	98.60	Ref. [6]
1223.00	99.60	Ref. [6]
1305.00	100.00	Ref. [6]
1338.00	100.00	Ref. [6]
1500.00	100.00	Ref. [6]

5.1.20 Carbon Steel

The default tabular values of thermal conductivity as a function of temperature for carbon steel are listed below. No extrapolation is allowed.

Carbon Steel

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
273.15	45.437	Ref. [8]
373.15	44.229	Ref. [8]
473.15	42.681	Ref. [8]

Carbon Steel

Temp (K)	Thermal Conductivity (W/m-K)	Data Source
573.15	40.794	Ref. [8]
673.15	38.568	Ref. [8]
773.15	36.002	Ref. [8]
873.15	33.098	Ref. [8]
973.15	29.854	Ref. [8]
1076.80	26.135	Ref. [8]
1173.15	27.100	Ref. [8]
1273.15	28.100	Ref. [8]
1373.15	29.100	Ref. [8]
1473.15	30.100	Ref. [8]
1573.15	31.100	Ref. [8]
1673.15	32.100	Ref. [8]
1773.15	33.100	Ref. [8]
1810.90	33.477	Ref. [8]
5000.00	33.477	Ref. [8]

5.2 Eucken Correlation for a Single, Pure Gas

The thermal conductivity, λ_i , of a single low-pressure gas may be computed using the Eucken correlation [13]:

$$\lambda_i = \left(C_{vi} + \frac{9R}{4M_i} \right) \mu_i \quad (W / m - K) \quad (5.2.1)$$

where,

C_{vi} = heat capacity at constant volume (J/kg-K), calculated by the NCG package (see the NCG/H2O Package Reference Manual)

R = universal gas constant, 8.31441 J/mol-K

μ_i = viscosity (kg/m-s), calculated by the MP package (see Section 6)

M_i = molecular weight (kg/mol), set by the NCG package

5.3 Wassijewa Equation for a Combination of Low-Pressure Gases

The thermal conductivity, λ_{mix} , of a combination of gases may be computed using the Wassijewa equation with the Mason and Saxena modification for the A_{ij} term [13]:

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$$\lambda_{mix} = \sum_{i=1}^n \frac{\lambda_i y_i}{\sum_{j=1}^n y_j A_{ij}} \quad (5.3.1)$$

where,

y_i = mole fraction of gas i

λ_i = thermal conductivity of pure gas i (see Section 5.2)

$$A_{ij} = \frac{[1 + (\mu_i / \mu_j)^{1/2} (M_j / M_i)^{1/4}]^2}{[8(1 + M_i / M_j)]^{1/2}}$$

$$= \frac{1}{\sqrt{8}} \left(\frac{M_j}{M_i} \right) \left(\frac{M_i}{M_j + M_i} \right)^{1/2} \left[\left(\frac{M_i}{M_j} \right)^{1/4} + \left(\frac{\mu_i}{\mu_j} \right)^{1/2} \right]^2$$

μ_i = viscosity of pure gas i (kg/m-s), (see Section 6)

M_i = molecular weight of gas i (kg/mol), set by the NCG package

The mole fractions, y_i , may be expressed in terms of the gas masses, m_i , using,

$$y_i = \frac{m_i / M_i}{\sum_{i=1}^n m_i / M_i} \quad (5.3.2)$$

yielding,

$$\lambda_{mix} = \sum_{i=1}^n \frac{m_i \lambda_i}{\sum_{j=1}^n m_j \left(\frac{M_i}{M_j} \right) A_{ij}} \quad (5.3.3)$$

or

$$\lambda_{mix} = \sqrt{8} \sum_{i=1}^n \frac{m_i \lambda_i}{\sum_{j=1}^n m_j \left(\frac{M_i}{M_j + M_i} \right)^{1/2} \left[\left(\frac{M_i}{M_j} \right)^{1/4} + \left(\frac{\mu_i}{\mu_j} \right)^{1/2} \right]^2} \quad (5.3.4)$$

6. Dynamic Viscosity as a Function of Temperature

The dynamic viscosity may be computed from two different methods. One method, used for structural materials in the COR and HS packages, utilizes tabular data which may be either a user-specified tabular function or a MELCOR default table. The other method, used for noncondensable gases and optionally for steam and air, utilizes the Chapman-Enskog equations for low-pressure gases based on constant Lennard-Jones potential parameters, σ and ε / k , which may be either user-specified or MELCOR default values.

6.1 Tabular

The user-specified tabular function to define a new material or to override the default table for an existing material is invoked by using a standard tabular function (see the TF Package Users' Guide) to input the viscosity (kg/m-s) as a function of temperature (K).

The following materials have default tables for viscosity:

- Water
- Steam
- Air
- Hydrogen
- Deuterium

The default viscosity values are computed by linear interpolation of the tabulated values listed below. Data sources are given with each table.

6.1.1 Water

The default tabular values of dynamic viscosity as a function of temperature for liquid water are listed below. No extrapolation is allowed.

Water

Temp (K)	Dynamic Viscosity (kg/m-s)	Data Source
255.370	0.00264402	Ref. [11]
283.148	0.00130962	Ref. [11]
310.926	0.000681596	Ref. [11]
338.704	0.000434554	Ref. [11]
366.482	0.000305081	Ref. [11]
394.260	0.000235136	Ref. [11]
422.038	0.000186025	Ref. [11]
449.816	0.000156261	Ref. [11]
477.594	0.000135426	Ref. [11]
499.850	0.000117267	Ref. [11]

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Water

Temp (K)	Dynamic Viscosity (kg/m-s)	Data Source
522.050	0.000106999	Ref. [11]
544.250	0.0000985165	Ref. [11]
566.450	0.0000915221	Ref. [11]
588.750	0.0000833372	Ref. [11]
610.950	0.0000723248	Ref. [11]
633.150	0.0000581872	Ref. [11]
647.245	0.0000492111	Ref. [14], p. 103

6.1.2 Steam

The default tabular values of dynamic viscosity as a function of temperature for steam are listed below. Linear extrapolation is allowed from the upper end of the tabulated range. No extrapolation is allowed from the lower end of the tabulated range.

Steam

Temp (K)	Dynamic Viscosity (kg/m-s)	Data Source
255.15	0.00000724	Ref. [9]
273.15	0.00000804	Ref. [9]
313.15	0.00000966	Ref. [9]
353.15	0.0000113	Ref. [9]
393.15	0.0000129	Ref. [9]
433.15	0.0000146	Ref. [9]
473.15	0.0000162	Ref. [9]
513.15	0.0000178	Ref. [9]
553.15	0.0000194	Ref. [9]
593.15	0.0000211	Ref. [9]
633.15	0.0000227	Ref. [9]
673.15	0.0000243	Ref. [9]
713.15	0.0000260	Ref. [9]
753.15	0.0000276	Ref. [9]
793.15	0.0000292	Ref. [9]
833.15	0.0000308	Ref. [9]
873.15	0.0000325	Ref. [9]
913.15	0.0000341	Ref. [9]
953.15	0.0000357	Ref. [9]
993.15	0.0000375	Ref. [9]
1033.15	0.0000391	Ref. [9]
1073.15	0.0000406	Ref. [9]
1200.00	0.0000454	Ref. [9]
1400.00	0.0000512	Ref. [9]
1600.00	0.0000563	Ref. [9]
1800.00	0.0000612	Ref. [9]

Steam

Temp (K)	Dynamic Viscosity (kg/m-s)	Data Source
2000.00	0.0000659	Ref. [9]
2200.00	0.0000703	Ref. [9]
2400.00	0.0000742	Ref. [9]
2600.00	0.0000775	Ref. [9]
2800.00	0.0000798	Ref. [9]
3000.00	0.0000810	Ref. [9]
3200.00	0.0000814	Ref. [9]
3400.00	0.0000816	Ref. [9]
3600.00	0.0000825	Ref. [9]
3800.00	0.0000851	Ref. [9]
4000.00	0.0000895	Ref. [9]

6.1.3 Air

The default tabular values of dynamic viscosity as a function of temperature for air are listed below. Linear extrapolation is allowed from the upper end of the tabulated range. No extrapolation is allowed from the lower end of the tabulated range.

Air

Temp (K)	Dynamic Viscosity (kg/m-s)	Data Source
99.820	0.00000852739	Ref. [9]
299.820	0.0000184686	Ref. [9]
499.820	0.0000267132	Ref. [9]
699.820	0.0000333208	Ref. [9]
899.820	0.0000389908	Ref. [9]
1099.820	0.0000439763	Ref. [9]
1299.820	0.0000484856	Ref. [9]
1499.820	0.0000525781	Ref. [9]
1699.820	0.0000564325	Ref. [9]
1899.820	0.0000599596	Ref. [9]
2099.820	0.0000640075	Ref. [9]
2299.820	0.0000671625	Ref. [9]
2499.820	0.0000698561	Ref. [9]
2699.820	0.0000723414	Ref. [9]

6.1.4 Hydrogen

The default tabular values of dynamic viscosity as a function of temperature for hydrogen are listed below. Linear extrapolation is allowed from the upper end of the tabulated range. No extrapolation is allowed from the lower end of the tabulated range.

Hydrogen

Temp (K)	Dynamic Viscosity (kg/m-s)	Data Source
100.0	0.0000042105	Ref. [15], p.284
200.0	0.0000068129	Ref. [15], p.284
250.0	0.0000079232	Ref. [15], p.284
280.0	0.0000085523	Ref. [15], p.284
300.0	0.0000089594	Ref. [15], p.284
400.0	0.000010867	Ref. [15], p.284
500.0	0.000012642	Ref. [15], p.284
600.0	0.000014290	Ref. [15], p.284
700.0	0.000015846	Ref. [15], p.284
800.0	0.000017335	Ref. [15], p.284
900.0	0.000018756	Ref. [15], p.284
1000.0	0.000020128	Ref. [15], p.284
1100.0	0.000021440	Ref. [15], p.284
1200.0	0.000022754	Ref. [16]
1300.0	0.000024078	Ref. [16]
4000.0	0.000059839	Ref. [16], extrapolated

6.1.5 Deuterium

The default tabular values of dynamic viscosity as a function of temperature for deuterium are listed below. No extrapolation is allowed from the lower end of the tabulated range. Linear extrapolation is allowed from the upper end of the tabulated range.

Deuterium

Temp (K)	Dynamic Viscosity (kg/m-s)	Data Source
100.0	0.00000579	Ref. [6]
120.0	0.00000662	Ref. [6]
140.0	0.00000739	Ref. [6]
160.0	0.00000814	Ref. [6]
180.0	0.00000885	Ref. [6]
200.0	0.00000955	Ref. [6]
220.0	0.00001022	Ref. [6]
240.0	0.00001087	Ref. [6]
260.0	0.00001151	Ref. [6]
280.0	0.00001214	Ref. [6]
300.0	0.00001274	Ref. [6]
320.0	0.00001332	Ref. [6]
340.0	0.00001388	Ref. [6]
360.0	0.00001445	Ref. [6]
380.0	0.00001501	Ref. [6]
400.0	0.00001554	Ref. [6]
420.0	0.00001606	Ref. [6]

Deuterium

Temp (K)	Dynamic Viscosity (kg/m-s)	Data Source
440.0	0.00001658	Ref. [6]
460.0	0.00001709	Ref. [6]
480.0	0.00001758	Ref. [6]
500.0	0.00001805	Ref. [6]

6.2 Chapman-Enskog Equation for a Single, Pure Gas

$$\mu_i = 2.6693 \times 10^{-6} \frac{\sqrt{1000 M T}}{\sigma^2 \Omega_v} \quad \text{kg/m-s} \quad (6.2.1)$$

The viscosity, μ_i , of a single, low-pressure gas may be computed using the Chapman-Enskog viscosity equation [17]:

where,

M = molecular weight (kg/mol)

T = gas temperature (K)

σ = collision diameter ($\text{\AA} \equiv 10^{-10}\text{m}$)

Ω_v = collision integral

$$= 2.785 \left(\frac{T^*}{0.3} \right)^{-0.4} \quad T^* < 0.3 \text{ (extrapolated)}$$

$$= f(T^*) \text{ from Table 6.1 below} \quad 0.3 \leq T^* < 100$$

$$= 0.5882 \left(\frac{T^*}{100} \right)^{-0.145} \quad T^* \geq 100$$

$$T^* = \frac{k T}{\varepsilon}$$

ε / k = characteristic energy/Boltzmann's constant (K)

The following materials have default tables for the Lennard-Jones potential parameters, σ and ε / k [13, 18]:

$$\sigma(\text{\AA}) \quad \varepsilon / k \text{ (K)}$$

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	σ (Å)	ε / k (K)
Steam	2.641	809.1
Air	3.711	78.6
Hydrogen	2.827	59.7
Helium	2.551	10.22
Argon	3.542	93.3
Deuterium	2.948	39.3
Oxygen	3.467	106.7
Carbon Dioxide	3.941	195.2
Carbon Monoxide	3.690	91.7
Nitrogen	3.798	71.4
Nitric Oxide	3.492	116.7
Nitrous Oxide	3.828	232.4
Ammonia	2.900	558.3
Acetylene	4.033	231.8
Methane	3.758	148.6
Ethylene	4.163	224.7
Uranium Hexafluoride	5.967	236.8

The default values for σ and ε / k may be changed using the mnemonics SIG and EPS as described in the MP Users' Guide.

Table 6.1. Collision Integral, Ω_v , as a Function of the Dimensionless Temperature, T^* [17].

T^*	Ω_v	T^*	Ω_v	T^*	Ω_v
0.30	2.785	1.65	1.264	4.00	0.9700
0.35	2.628	1.70	1.248	4.10	0.9649
0.40	2.492	1.75	1.234	4.20	0.9600
0.45	2.368	1.80	1.221	4.30	0.9553
0.50	2.257	1.85	1.209	4.40	0.9507
0.55	2.156	1.90	1.197	4.50	0.9464
0.60	2.065	1.95	1.186	4.60	0.9422
0.65	1.982	2.00	1.175	4.70	0.9382
0.70	1.908	2.10	1.156	4.80	0.9343
0.75	1.841	2.20	1.138	4.90	0.9305
0.80	1.780	2.30	1.122	5.00	0.9269
0.85	1.725	2.40	1.107	6.00	0.8963
0.90	1.675	2.50	1.093	7.00	0.8727
0.95	1.629	2.60	1.081	8.00	0.8538

T*	Ω_v	T*	Ω_v	T*	Ω_v
1.00	1.587	2.70	1.069	9.00	0.8379
1.05	1.549	2.80	1.058	10.00	0.8242
1.10	1.514	2.90	1.048	20.00	0.7432
1.15	1.482	3.00	1.039	30.00	0.7005
1.20	1.452	3.10	1.030	40.00	0.6718
1.25	1.424	3.20	1.022	50.00	0.6504
1.30	1.399	3.30	1.014	60.00	0.6335
1.35	1.375	3.40	1.007	70.00	0.6194
1.40	1.353	3.50	0.9999	80.00	0.6076
1.45	1.333	3.60	0.9932	90.00	0.5973
1.50	1.314	3.70	0.9870	100.00	0.5882
1.55	1.296	3.80	0.9811		
1.60	1.279	3.90	0.9755		

6.3 Chapman-Enskog Equation for a Combination of Low-Pressure Gases

The viscosity of a mixture of gases can be computed by combining the individual viscosities of the pure substances using the following equation with the Wilke's approximation for the term, φ_{ij} [13]

$$\mu_{mix} = \frac{\sum_{i=1}^n y_i \mu_i}{\sum_{j=1}^n y_j \varphi_{ij}} \quad (6.3.1)$$

where,

y_i = mole fraction of gas i

μ_i = viscosity of pure gas i (see Section 6.2)

$$\begin{aligned} \varphi_{ij} &= \frac{\left[1 + (\mu_i / \mu_j)^{1/2} (M_j / M_i)^{1/4}\right]^2}{\left[8(1 + M_i / M_j)\right]^{1/2}} \\ &= \frac{1}{\sqrt{8}} \left(\frac{M_j}{M_i}\right) \left(\frac{M_i}{M_j + M_i}\right)^{1/2} \left[\left(\frac{M_i}{M_j}\right)^{1/4} + \left(\frac{\mu_i}{\mu_j}\right)^{1/2} \right]^2 \end{aligned}$$

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M_i = molecular weight of gas i (kg/mol), set by the NCG package

The mole fractions, y_i , may be expressed in terms of the gas masses, m_i , using,

$$y_i = \frac{m_i / M_i}{\sum_{j=1}^n m_j / M_j} \quad (6.3.2)$$

yielding,

$$\mu_{mix} = \sum_{i=1}^n \frac{m_i \mu_i}{\sum_{j=1}^n m_j \left(\frac{M_i}{M_j} \right) \phi_{ij}} \quad (6.3.3)$$

or

$$\mu_{mix} = \sqrt{8} \sum_{i=1}^n \frac{m_i \mu_i}{\sum_{j=1}^n m_j \left(\frac{M_i}{M_j + M_i} \right)^{1/2} \left[\left(\frac{M_i}{M_j} \right)^{1/4} + \left(\frac{\mu_i}{\mu_j} \right)^{1/2} \right]^2} \quad (6.3.4)$$

7. Binary Mass Diffusion Coefficient

The binary diffusion coefficients are computed using two different methods depending on which MELCOR package requires the information. The diffusion coefficients required for COR, CVH, and HS packages are computed by the MP package using the equations given in Section 7.1, below. RN1 utilizes the MP package noncondensable gas Lennard-Jones parameters for the calculation of fission product vapor binary diffusion coefficients as described in Section 7.2.

7.1 Binary Mass Diffusion Coefficient as a Function of Temperature and Pressure

The diffusion coefficient is computed from different correlations for each pair of materials. The diffusion coefficient (m^2/s) is defined as a function of temperature (K) and pressure (Pa) for two pairs of materials.

For steam and air, the following correlation is used (origin unknown):

$$D = 4.7931 \times 10^{-5} \left(\frac{T^{1.9}}{P} \right) \quad (7.1.1)$$

For steam and hydrogen, the correlation is taken from Reference [19]:

$$D = 6.60639 \times 10^{-4} \left(\frac{T^{1.68}}{P} \right) \quad (7.1.2)$$

An error message is printed if the input temperature or pressure is less than zero. There is currently no means by which the user can change these correlations.

7.2 Chapman-Enskog Equation for a Pair of Low-Pressure Gases

The binary diffusion coefficient, D_{AB} , for a pair of low-pressure gases may be computed using the Chapman-Enskog equation [17]:

$$D_{AB} = 1.88292 \times 10^{-2} \frac{\sqrt{T^3 \left(\frac{0.001}{M_A} + \frac{0.001}{M_B} \right)}}{P \sigma_{AB}^2 \Omega_{D,AB}} \quad m^2 / s \quad (7.2.1)$$

where,

- M_A = molecular weight of gas A (kg/mol)
- M_B = molecular weight of gas B (kg/mol)
- T = gas temperature (K)
- P = gas pressure (Pa)
- σ_A = collision diameter of gas A ($\text{\AA} \equiv 10^{-10}\text{m}$)
- σ_B = collision diameter of gas B ($\text{\AA} \equiv 10^{-10}\text{m}$)
- σ_{AB} = effective collision diameter of gas A and B ($\text{\AA} \equiv 10^{-10}\text{m}$)
 - = $1/2(\sigma_A + \sigma_B)$
- $\Omega_{D,AB}$ = collision integral
 - = $2.662 (T_{AB}^*/0.3)^{-0.5}$ $T_{AB}^* < 0.3$ (extrapolated)

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$= f(T_{AB}^*)$ from Table 7.1 below $0.3 \leq T_{AB}^* < 100$

$= 0.5170(T_{AB}^*/100)^{-0.155}$ $T_{AB}^* \geq 100$ (extrapolated)

$$T_{AB}^* = (k T / \varepsilon_{AB})$$

ε_{AB}/k = effective characteristic energy/Boltzmann's constant for gas A and B (K)

$$= 1/k (\varepsilon_A \varepsilon_B)^{1/2}$$

ε_A/k = effective characteristic energy/Boltzmann's constant for gas A (K)

ε_B/k = effective characteristic energy/Boltzmann's constant for gas B (K)

The table of Lennard-Jones potential parameters, σ and ε/k , is given in Section 6.2. The default values for σ and ε/k may be changed using the mnemonics SIG and EPS as described in the MP Users' Guide.

Table 7.1. Collision Integral, Ω_D , as a Function of Dimensionless Temperature, T_{AB}^* [17].

T_{AB}^*	Ω_D	T_{AB}^*	Ω_D	T_{AB}^*	Ω_D
0.30	2.662	1.65	1.153	4.00	0.8836
0.35	2.476	1.70	1.140	4.10	0.8788
0.40	2.318	1.75	1.128	4.20	0.8740
0.45	2.184	1.80	1.116	4.30	0.8694
0.50	2.066	1.85	1.105	4.40	0.8652
0.55	1.966	1.90	1.094	4.50	0.8610
0.60	1.877	1.95	1.084	4.60	0.8568
0.65	1.798	2.00	1.075	4.70	0.8530
0.70	1.729	2.10	1.057	4.80	0.8492
0.75	1.667	2.20	1.041	4.90	0.8456
0.80	1.612	2.30	1.026	5.00	0.8422
0.85	1.562	2.40	1.012	6.00	0.8124
0.90	1.517	2.50	0.9996	7.00	0.7896
0.95	1.476	2.60	0.9878	8.00	0.7712
1.00	1.439	2.70	0.9770	9.00	0.7556
1.05	1.406	2.80	0.9672	10.00	0.7424

T_{AB}^*	Ω_D	T_{AB}^*	Ω_D	T_{AB}^*	Ω_D
1.10	1.375	2.90	0.9576	20.00	0.6640
1.15	1.346	3.00	0.9490	30.00	0.6232
1.20	1.320	3.10	0.9406	40.00	0.5960
1.25	1.296	3.20	0.9328	50.00	0.5756
1.30	1.273	3.30	0.9256	60.00	0.5596
1.35	1.253	3.40	0.9186	70.00	0.5464
1.40	1.233	3.50	0.9120	80.00	0.5352
1.45	1.215	3.60	0.9058	90.00	0.5256
1.50	1.198	3.70	0.8998	100.00	0.5170
1.55	1.182	3.80	0.8942		
1.60	1.167	3.90	0.8888		

7.3 Chapman-Enskog Equation for a Combination of Low-Pressure Gases

The effective binary diffusion coefficient, D_{im} , for gas i in a mixture of m low-pressure gases can be computed as [17]:

$$\frac{1 - y_i}{D_{im}} = \sum_{j=1, \neq i}^m \left(\frac{y_j}{D_{ij}} \right) \quad (7.3.1)$$

where,

y_i = mole fraction of gas i, and

D_{ij} = binary diffusion coefficient for gas pair ij (m^2/s).

8. Density

The density of most materials may be computed as a constant value, a user-specified tabular function or a MELCOR default table. The default function for the densities of air and steam, however, are fixed by the code and cannot be changed through user input.

8.1 Constant Density

The constant density may be input by the user or read from a MELCOR default table. There are no checks made on the consistency of user-input values for enthalpy, specific heat capacity, melting temperature, and latent heat of fusion.

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The following materials have default values for the constant density:

Material	Density (kg/m ³)	Data Source
Zircaloy	6500.0	Ref. [20]
Zirconium Oxide	5600.0	Ref. [20]
Uranium Dioxide	10960.0	Ref. [20]
Stainless Steel	7930.0	Ref. [20]
Stainless Steel Oxide	5180.0	Ref. [20]
Boron Carbide	2520.0	Ref. [20]
Silver-Indium-Cadmium	9689.4	Ref. [2], @ 1000 K
Uranium Metal	18210.0	Ref. [11], p. 78
Graphite	1730.0	Ref. [4], p. 436
Carbon Steel	7752.9	Ref. [8]

8.2 Tabular as a Function of Temperature

The user-specified tabular function to define a new material or to override the default table for an existing material is invoked by using a standard tabular function (see the TF Package Users' Guide) to input the density (kg/m³) as a function of temperature (K). The densities used by the COR and FDI packages (see the users' guides for these packages) for user-defined tabular functions will be determined by evaluating the respective tabular functions at 1000 K. If the input tabular function does not allow an evaluation to be made at 1000 K, an input error occurs. Currently, only constant functions should be user-input, since temperature dependent values are not addressed by the HS package.

The following materials have default tables for density which may be altered through user input tabular functions:

Zircaloy
Zirconium Oxide
Uranium Dioxide
Stainless Steel
Stainless Steel Oxide
Boron Carbide
Silver-Indium-Cadmium
Uranium Metal
Graphite
Concrete

The default density values for the above materials are computed by linear interpolation of the tabulated values listed in Sections 8.2.1 through 8.2.11, below. Data sources are given with each table.

8.2.1 Zircaloy

The default tabular values of density as a function of temperature for Zircaloy are listed below. No extrapolation is allowed.

Zircaloy

Temp (K)	Density (kg/m ³)	Data Source
273.15	6500.0	Ref. [20]
5000.0	6500.0	Ref. [20]

8.2.2 Zirconium Oxide

The default tabular values of density as a function of temperature for zirconium oxide are listed below. No extrapolation is allowed.

Zirconium Oxide

Temp (K)	Density (kg/m ³)	Data Source
273.15	5600.0	Ref. [20]
5000.0	5600.0	Ref. [20]

8.2.3 Uranium Dioxide

The default tabular values of density as a function of temperature for uranium dioxide are listed below. No extrapolation is allowed.

Uranium Dioxide

Temp (K)	Density (kg/m ³)	Data Source
273.15	10960.0	Ref. [20]
5000.0	10960.0	Ref. [20]

8.2.4 Stainless Steel

The default tabular values of density as a function of temperature for stainless steel are listed below. No extrapolation is allowed.

Stainless Steel

Temp (K)	Density (kg/m ³)	Data Source
273.15	7930.0	Ref. [20]
5000.0	7930.0	Ref. [20]

8.2.5 Stainless Steel Oxide

The default tabular values of density as a function of temperature for stainless steel oxide are listed below. No extrapolation is allowed.

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Stainless Steel Oxide

Temp (K)	Density (kg/m ³)	Data Source
273.15	5180.0	Ref. [20]
5000.0	5180.0	Ref. [20]

8.2.6 Boron Carbide

The default tabular values of density as a function of temperature for boron carbide are listed below. No extrapolation is allowed.

Boron Carbide

Temp (K)	Density (kg/m ³)	Data Source
273.15	2520.0	Ref. [20]
5000.0	2520.0	Ref. [20]

8.2.7 Silver-Indium-Cadmium

The default tabular values of density as a function of temperature for silver-indium-cadmium are listed below. No extrapolation is allowed.

Silver-Indium-Cadmium

Temp (K)	Density (kg/m ³)	Data Source
273.15	9689.4	Ref. [2], @ 1000 K
5000.0	9689.4	Ref. [2], @ 1000 K

8.2.8 Uranium Metal

The default tabular values of density as a function of temperature for uranium metal are listed below. No extrapolation is allowed.

Uranium Metal

Temp (K)	Density (kg/m ³)	Data Source
273.15	19080.0	Ref. [11] p. 78, extrapolated
298.0	19050.0	Ref. [11] p. 78
366.3	18970.0	Ref. [11] p. 78
477.4	18870.0	Ref. [11] p. 78
588.6	18760.0	Ref. [11] p. 78
699.7	18640.0	Ref. [11] p. 78
810.8	18500.0	Ref. [11] p. 78
921.9	18330.0	Ref. [11] p. 78
1406.0	17580.0	Ref. [11], p. 78, extrapolated
5000.0	17580.0	Constant beyond melting point of 1406 K

8.2.9 Graphite

The default tabular values of density as a function of temperature for graphite are listed below. No extrapolation is allowed.

Graphite

Temp (K)	Density (kg/m ³)	Data Source
273.15	1730.0	Ref. [4], p. 436, nuclear graphite, grade A
5000.0	1730.0	Ref. [4] p. 436, nuclear graphite, grade A

8.2.10 Concrete

The default tabular values of density as a function of temperature for concrete are listed below. No extrapolation is allowed.

Concrete

Temp (K)	Density (kg/m ³)	Data Source
273.15	2306.7	Ref. [5], p. 635, stone concrete @ 294 K
5000.0	2306.7	Ref. [5], p. 635, stone concrete @ 294 K

8.2.11 Aluminum

The default tabular values of density as a function of temperature for aluminum are listed below. Constant extrapolation is allowed from the lower end of the tabulated range. Linear extrapolation is allowed from the upper end of the tabulated range.

Aluminum

Temp (K)	Density (kg/m ³)	Data Source
273.15	2705.00	Ref. [6]
300.00	2701.00	Ref. [6]
400.00	2681.00	Ref. [6]
500.00	2661.00	Ref. [6]
600.00	2639.00	Ref. [6]
800.00	2591.00	Ref. [6]
933.00	2559.00	Ref. [6]
933.01	2385.00	Ref. [6]
1000.00	2365.00	Ref. [6]
1200.00	2305.00	Ref. [6]
1400.00	2255.00	Ref. [6]

8.2.12 Aluminum Oxide

The default tabular values of density as a function of temperature for aluminum oxide are listed below. Linear extrapolation is allowed from the upper end of the tabulated range.

Aluminum Oxide

Temp (K)	Density (kg/m ³)	Data Source
273.15	4000.0	Ref. [7]
5000.0	4000.0	Ref. [7]

8.2.13 Cadmium

The default tabular values of density as a function of temperature for cadmium are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Cadmium

Temp (K)	Density (kg/m ³)	Data Source
273.15	8670.0	Ref. [6]
283.15	8660.0	Ref. [6]
293.15	8650.0	Ref. [6]
303.15	8640.0	Ref. [6]
313.15	8630.0	Ref. [6]
323.15	8620.0	Ref. [6]
333.15	8610.0	Ref. [6]
343.15	8600.0	Ref. [6]
353.15	8590.0	Ref. [6]
363.15	8580.0	Ref. [6]
373.15	8570.0	Ref. [6]
383.15	8561.0	Ref. [6]
393.15	8551.0	Ref. [6]
403.15	8541.0	Ref. [6]
413.15	8531.0	Ref. [6]
423.15	8521.0	Ref. [6]
433.15	8511.0	Ref. [6]
443.15	8501.0	Ref. [6]
453.15	8491.0	Ref. [6]
463.15	8481.0	Ref. [6]
473.15	8470.0	Ref. [6]
483.15	8460.0	Ref. [6]
493.15	8450.0	Ref. [6]
503.15	8439.0	Ref. [6]
513.15	8428.0	Ref. [6]
523.15	8417.0	Ref. [6]
533.15	8406.0	Ref. [6]
543.15	8395.0	Ref. [6]
553.15	8384.0	Ref. [6]
563.15	8372.0	Ref. [6]
573.15	8360.0	Ref. [6]
583.15	8348.0	Ref. [6]

Cadmium

Temp (K)	Density (kg/m ³)	Data Source
594.00	8336.0	Ref. [6]
594.01	8016.0	Ref. [6]
600.00	8010.0	Ref. [6]
800.00	7805.0	Ref. [6]
1000.00	7590.0	Ref. [6]
1040.00	7547.0	Ref. [6]

8.2.14 Stainless Steel 304

The default tabular values of density as a function of temperature for stainless steel 304 are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Stainless Steel 304

Temp (K)	Density (kg/m ³)	Data Source
273.15	8025.00	Ref. [6]
323.15	8003.00	Ref. [6]
373.15	7981.00	Ref. [6]
423.15	7958.00	Ref. [6]
473.15	7936.00	Ref. [6]
523.15	7914.00	Ref. [6]
573.15	7891.00	Ref. [6]
623.15	7869.00	Ref. [6]
673.15	7847.00	Ref. [6]
723.15	7824.00	Ref. [6]
773.15	7802.00	Ref. [6]
823.15	7780.00	Ref. [6]
873.15	7757.00	Ref. [6]
923.15	7735.00	Ref. [6]
973.15	7713.00	Ref. [6]
1023.15	7690.00	Ref. [6]
1073.15	7668.00	Ref. [6]
1123.15	7646.00	Ref. [6]
1173.15	7623.00	Ref. [6]
1223.15	7601.00	Ref. [6]
1273.15	7579.00	Ref. [6]
1373.15	7534.00	Ref. [6]
1473.15	7489.00	Ref. [6]
1573.15	7445.00	Ref. [6]
1673.15	7400.00	Ref. [6]
1700.00	7388.00	Ref. [6]
1700.01	6926.00	Ref. [6]
1800.00	6862.00	Ref. [6]

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Stainless Steel 304

Temp (K)	Density (kg/m ³)	Data Source
1900.00	6785.00	Ref. [6]
2000.00	6725.00	Ref. [6]
2100.00	6652.00	Ref. [6]
2200.00	6576.00	Ref. [6]
2300.00	6498.00	Ref. [6]
2400.00	6416.00	Ref. [6]
2500.00	6331.00	Ref. [6]
2600.00	6243.00	Ref. [6]
2700.00	6152.00	Ref. [6]
2800.00	6058.00	Ref. [6]
2900.00	5961.00	Ref. [6]
3000.00	5861.00	Ref. [6]

8.2.15 Lithium Aluminum

The default tabular values of density as a function of temperature for lithium aluminum are listed below. Constant extrapolation is allowed from the lower end of the tabulated range. Linear extrapolation is allowed from the upper end of the tabulated range.

Lithium Aluminum

Temp (K)	Density (kg/m ³)	Data Source
273.15	2664.00	Ref. [6]
300.00	2660.00	Ref. [6]
400.00	2640.00	Ref. [6]
500.00	2620.00	Ref. [6]
600.00	2600.00	Ref. [6]
800.00	2551.00	Ref. [6]
917.00	2524.00	Ref. [6]
917.01	2348.00	Ref. [6]
1000.00	2328.00	Ref. [6]
1200.00	2269.00	Ref. [6]
1400.00	2120.00*	Ref. [6]*

* Value differs slightly from reference. MELCOR/SR-Mod3 Fortran value is used.

8.2.16 Uranium Aluminum

The default tabular values of density as a function of temperature for uranium aluminum are listed below. Constant extrapolation is allowed from both ends of the tabulated range.

Uranium Aluminum

Temp (K)	Density (kg/m ³)	Data Source
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Uranium Aluminum

Temp (K)	Density (kg/m ³)	Data Source
400.00	3507.00*	Ref. [6]*
500.00	3469.00	Ref. [6]
600.00	3448.00	Ref. [6]
700.00	3425.00	Ref. [6]
800.00	3402.00	Ref. [6]
919.00	3371.00	Ref. [6]
919.01	3202.00	Ref. [6]
962.00	3196.00	Ref. [6]
1005.00	3180.00	Ref. [6]
1005.01	3260.00	Ref. [6]
1039.00	3197.00	Ref. [6]
1123.00	3159.00	Ref. [6]
1223.00	3117.00	Ref. [6]
1323.00	3076.00	Ref. [6]
1338.00	3071.00	Ref. [6]
1400.00	3051.00	Ref. [6]

* Value differs slightly from reference. MELCOR/SR-Mod3 Fortran value is used.

8.2.17 Carbon Steel

The default tabular values of density as a function of temperature for carbon steel are listed below. No extrapolation is allowed.

Carbon Steel

Temp (K)	Density (kg/m ³)	Data Source
273.15	7752.9	Ref. [8]
5000.00	7752.9	Ref. [8]

8.3 Calculated as a Function of Temperature and Pressure

The default density functions for air and steam are described in Sections 8.3.1 and 8.3.2, below. These default functions may not be altered through user input.

8.3.1 Air

The density (kg/m³) of air is computed from the gas law:

$$\rho = MW \times Pres / (R \times T \times CPRS) \quad (8.3.1)$$

where,

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MW = Molecular weight, 0.028966 kg/mol
Pres = Pressure (Pa)
R = Universal gas constant, 8.31441 J/(mol-K)
T = Temperature (K)
CPRS = Compressibility, 1.0

8.3.2 Steam

The density (kg/m^3) of steam is computed from the gas law:

$$\rho = MW \times \text{Pres} / (R \times T \times CPRS) \quad (8.3.2)$$

where,

MW = Molecular Weight, 0.018016 kg/mol
Pres = Pressure (Pa)
R = Universal gas constant, 8.31441 J/(mol-K)
T = Temperature (K)
CPRS = Given

in

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Table 8.1 The value of CPRS is determined by standard interpolation on T and P for those points bounded by values from

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Table 8.1. For those points which lie outside the bounds of the table, various methods are used for determining CPRS. Figure 8.1 is a graphic illustration of the values shown on

Table 8.1. The figure is divided into 10 regions, each of which has its own method for computing the compressibility.

- Region 1: Points in this region are assigned a compressibility of 0.9978. This corresponds to the value of CPRS at (0.0068884 MPa, 311.72 K).
- Region 2: CPRS for points in this region are computed by linear interpolation on temperature of the values for the pressure, $P = 0.0068884$ MPa.
- Region 3: Points in this region are assigned a compressibility of 1.0000. This corresponds to the value of CPRS at (0.0068884 MPa, 1033.0 K).
- Region 4: CPRS for points in this region are computed by linear interpolation on pressure of the smallest values for the pressures on the left and right sides of (P, T).
- Region 5: CPRS for points in this region are computed by linear interpolation, first on temperature , then on pressure, of the bounding values on the left side and the value corresponding to the minimum temperatures on the right side.
- Region 6: CPRS for points in this region are computed by linear interpolation, first on temperature , then on pressure, of the bounding values.
- Region 7: Points in this region are assigned the maximum value for compressibility, 1.0000.
- Region 8: Points in this region are assigned a compressibility of 0.9134. This corresponds to the value of CPRS at (1.3786 MPa, 467.37 K).
- Region 9: CPRS for points in this region are computed by linear interpolation on temperature of the values for the pressure, $P = 1.3786$ MPa.
- Region 10: Points in this region are assigned a compressibility of 0.9995. This corresponds to the value at (1.3786 MPa, 1366.33 K).

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Table 8.1. Compressibility of Steam as a Function of Temperature (K) and Pressure (MPa) (Ref. 9).

Pressure (MPa)	0.0068884	0.034462	0.068953	0.10130	0.13786	0.27572	0.41358
Temp (K)							
311.72	0.9978						
345.34		0.9927					
362.55			0.9881				
366.33	0.9991	0.9946	0.9889				
372.99				0.9846			
381.87					0.9811		
388.55	0.9993	0.9959	0.9916				
388.56				0.9875	0.9825		
403.70						0.9702	
410.77	0.9995	0.9969	0.9936				
410.78				0.9905	0.9866	0.9726	
417.85							0.9610
428.59							
433.00	0.9997	0.9976	0.9950	0.9925	0.9898	0.9786	0.9672
437.37							
444.83							
451.38							
455.22	0.9998	0.9981	0.9960	0.9941	0.9919	0.9830	0.9739
457.22							
462.52							
467.37							
477.44	0.9999	0.9985	0.9967	0.9952	0.9934	0.9862	0.9789
499.67	1.0000	0.9988	0.9974	0.9959	0.9944	0.9886	0.9826
505.22							
533.00	1.0000	0.9991	0.9980	0.9969	0.9959	0.9913	0.9867
560.78							
588.56	1.0000	0.9995	0.9987	0.9981	0.9973	0.9941	0.9911
644.11	1.0000	0.9996	0.9992	0.9986	0.9982	0.9959	0.9938
699.67	1.0000	0.9998		0.9991	0.9987	0.9971	0.9956
755.22							
810.78	1.0000	1.0000	0.9998	0.9996	0.9994	0.9985	0.9976
921.89	1.0000	1.0000	1.0000	0.9999	0.9998	0.9992	0.9987
1033.00	1.0000	1.0000	1.0000	1.0000	0.9999	0.9997	0.9992
1144.11				1.0000	1.0000	0.9998	0.9998
1255.22						1.0000	1.0000
1366.33							1.0000
1477.44							

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Table 8.1 Compressibility of Steam as a Function of Temperature (K) and Pressure (MPa) (Ref. 9) (Cont)

Pressure (MPa)	0.55145	0.68931	0.82717	0.96502	1.1029	1.2407	1.3786
Temp (K)							
311.72							
345.34							
362.55							
366.33							
372.99							
381.87							
388.55							
388.56							
403.70							
410.77							
410.78							
417.85							
428.59	0.9528						
433.00	0.9552						
437.37		0.9432					
444.83			0.9383				
451.38				0.9316			
455.22	0.9646	0.9550	0.9449	0.9347			
457.22					0.9255		
462.52						0.9193	
467.37							0.9134
477.44	0.9714	0.9637	0.9561	0.9478	0.9397	0.9310	0.9223
499.67	0.9766	0.9703					
505.22			0.9657	0.9595	0.9533	0.9469	0.9406
533.00	0.9822	0.9775	0.9727	0.9681	0.9630	0.9580	0.9532
560.78			0.9779	0.9741	0.9701	0.9663	0.9622
588.56	0.9880	0.9850	0.9819	0.9787	0.9756	0.9723	0.9691
644.11	0.9916	0.9895	0.9872	0.9852	0.9830	0.9807	0.9785
699.67	0.9940	0.9924	0.9909	0.9893	0.9877	0.9861	0.9845
755.22						0.9899	0.9887
810.78	0.9967	0.9958	0.9950	0.9941	0.9933	0.9924	0.9916
921.89	0.9982	0.9976	0.9971	0.9966	0.9962	0.9956	0.9951
1033.00	0.9990	0.9986	0.9983	0.9980	0.9977	0.9974	0.9970
1144.11	0.9994	0.9992	0.9990	0.9989	0.9986	0.9984	0.9983
1255.22	0.9998	0.9996	0.9995	0.9994	0.9993	0.9991	0.9990
1366.33	1.0000	0.9999	0.9998	0.9998	0.9997	0.9996	0.9995
1477.44		1.0000			1.0000		

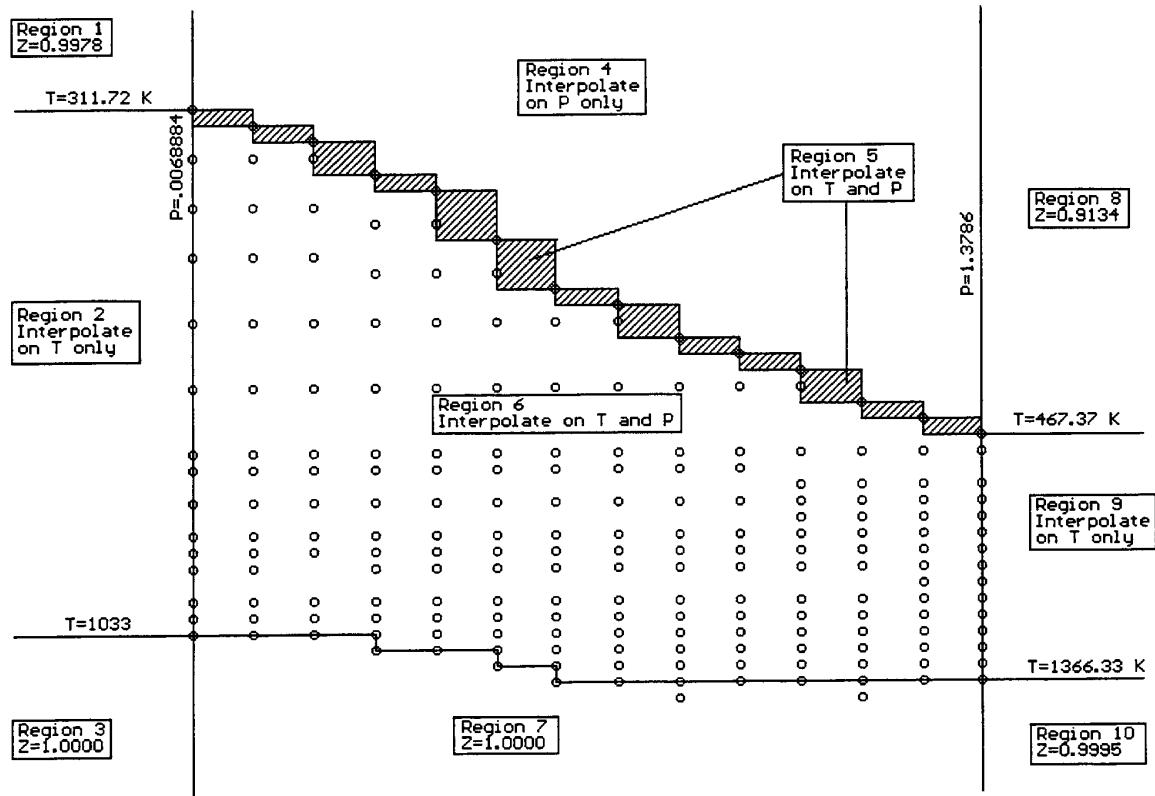


Figure 8.1. Methods for Computing the Compressibility from

Table 8.1 Data.

9. Constant Melting Temperature

The melting temperature may be input by the user or read from a MELCOR default table. There are no checks made on the consistency of user-input values for enthalpy, specific heat capacity, melting temperature, and latent heat of fusion.

The following materials have default tables for the melting temperature:

Material	Melt Temperature (K)	Data Source
Zircaloy	2098.0	Ref. [1]
Zirconium Oxide	2990.0	Ref [20]
Uranium Dioxide	3113.0	Ref. [1]
Stainless Steel	1700.0	Estimated
Stainless Steel Oxide	1870.0	Ref. [20], Fe ₃ O ₄
Boron Carbide	2620.0	Ref. [20]
Silver-Indium-Cadmium	1075.0	Ref. [2]
Uranium Metal	1406.0	Ref. [20]
Graphite	3866.0	Ref. [4]
Aluminum	933.0	Ref. [6]
Aluminum Oxide	2327.0	Ref. [7]
Cadmium	594.0	Ref. [6]
Stainless Steel 304	1700.0	Ref. [6]
Lithium Aluminum	917.0	Ref. [6]
Uranium Aluminum	1128.5	Ref. [6], average of solidus and liquidus points
Carbon Steel	1810.9	Ref. [8]

10. Constant Latent Heat of Fusion

The latent heat of fusion may be input by the user or read from a MELCOR default table. There are no checks made on the consistency of user-input values for enthalpy, specific heat capacity, melting temperature, and latent heat of fusion.

The following materials have default tables for the latent heat of fusion:

Material	Heat of Fusion (J/kg)	Data Source
Zircaloy	2.25E5	Ref. [1]
Zirconium Oxide	7.07E5	Ref [20]
Uranium Dioxide	2.74E5	Ref [1]
Stainless Steel	2.68E5	Estimated

Material	Heat of Fusion (J/kg)	Data Source
Stainless Steel Oxide	5.98E5	Ref. [20], Fe ₃ O ₄
Boron Carbide	5.00E5	Estimated
Silver-Indium-Cadmium	9.80E4	Ref. [2]
Uranium Metal	5.025E4	Ref. [4]
Aluminum Oxide	1.07E6	Ref. [21]
Aluminum	3.978E5	Ref. [6]
Cadmium	5.500E4	Ref. [6]
Stainless Steel 304	2.692E5	Ref. [6]
Lithium Aluminum	3.9845E5	Ref. [6]
Uranium Aluminum	2.900E5	Ref. [6]
Carbon Steel	2.71960E5	Ref. [8]

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